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BOSTON SOCIETY OF CIVIL ENGINEERS
FOUNDED 1848

PROCEEDINGS

PAPER IN THIS NUMBER.

"The Amoskeag Manufacturing Company Hydro-Electric Development." Arthur T. Safford.

Description of electrical equipment by H. H. Bodge.

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MINUTES OF MEETING.

BOSTON, February 21, 1923 — A regular meeting of the Boston Society of Civil Engineers was held this evening in Chipman Hall, Tremont Temple, and was called to order at 7.50 P.M. by the President, Dugald C. Jackson. There were about 130 members and guests present.

The minutes of the previous meeting were approved as printed in the February JOURNAL.

The Secretary reported for the Board of Government the names of those elected to membership.

Members — Messrs. Charles P. Foyer, Grant K. French, Frederick P. Nickerson, Thomas W. Proctor, Kenneth C. Reynolds*, and Timothy P. Riordan.

The President announced the death of Frank W. Hodgdon, a past President of the Society and a member for over forty

* Transferred from the Grade of Junior.

years, who died on January 26, 1923. A committee will be appointed by the President to prepare a memoir of Mr. Hodgdon.

The President announced the result of the letter ballot favoring the establishment of a National Hydraulic Laboratory: affirmative, 284 votes; negative, 11 votes.

The following amendment to the By-Laws was unanimously approved.

To amend Section 8 of the By-Laws by adding:

“A member of any grade who has paid dues for 40 years, or who has reached the age of 70 years and has paid dues for 30 years, shall be exempt from further dues.”

This amendment to the By-Laws, having been acted upon favorably by a two-thirds vote at two successive regular meetings, has now been adopted.

The President announced that the Council of the Affiliation had endorsed House Bill No. 295, providing for the establishment of a Division of Metropolitan Planning of the Metropolitan District Commission, and that representatives of the Council of the Affiliation and of the Board of Government of the Society had appeared at a legislative hearing in favor of this bill on February 15, 1923. The Board of Government reported that no further action of the Society is deemed necessary in this matter.

The President announced that the Board of Government, at the request of the Massachusetts Railroad Committee, had appointed a special committee to study the New England Railroad Problem. This committee, of which Prof. George F. Swain was chairman, was subsequently taken over as the Committee of the Affiliation. The Council of the Affiliation has recently adopted the majority report, signed by five members of this committee, and has submitted both the majority report and the minority report, signed by one member, to the Massachusetts Railroad Committee of which James J. Storrow is chairman. The Massachusetts committee is a part of a joint New England committee which is studying this problem. Copies of both reports are available in the library of the Society. The Board of Government reported that no further action is deemed necessary, unless desired by some member of the Society.

The Board of Government reported that it desired an expression of opinion from the membership on certain matters concerning the activities of the Society and has therefore voted to recommend that a letter ballot be taken by the Society on whether an assessment equal to 10 per cent. of the dues should be made for the ensuing year for the purposes of paying the dues to The Federated American Engineering Societies, and for improving the activities of the Society, including additional expenditures for the library.

It was unanimously voted at the meeting that a letter ballot be sent out in accordance with this recommendation of the Board of Government, the ballots to be canvassed at the Annual Meeting, March 21, 1923.

The President announced that the first Annual Dinner of The Affiliated Technical Societies of Boston would be held at the Copley Plaza Hotel on Wednesday, March 7, 1923, and he urged the members of the Society to attend this dinner and to do their share in making it a great success.

Professor Jackson presented L. W. Wallace, Executive Secretary, of the Federated American Engineering Societies, who spoke briefly on the work and progress of the Federation.

The professional program was in charge of Frank A. Marston, who introduced the speakers of the evening. The subject was "A Symposium on City Pavements" and the following speakers presented brief papers outlining their experiences with various types of pavements:

Lewis M. Hastings, City Engineer, Cambridge.

Edwin H. Rogers, City Engineer, Newton.

Henry A. Varney, Town Engineer, Brookline.

George H. Nye, City Engineer, New Bedford.

David A. Hartwell, Commissioner of Public Works, Fitchburg.

J. C. Blake, Street Commissioner, Worcester.

Robert P. Marsh, Superintendent of Streets and Engineering, Springfield,

Edgar S. Dorr, Special Engineer, Department of Public Works, Boston.

After the presentation of these papers, a discussion ensued in which members and guests took part. An interesting feature of the discussion was the possible use in this country of rubber pavements as a means of reducing noise in the vicinity of hospitals, public buildings, and residences, and in order to provide a satisfactory pavement on bridges in which the floor system was subject to excessive vibration.

At the conclusion of the meeting, a rising vote of thanks was given to those, not members of the Society, who had presented papers.

Meeting adjourned about 9.50 P.M.

J. B. BABCOCK,

Secretary.

APPLICATIONS FOR MEMBERSHIP.

[March 15, 1923.]

THE By-Laws provide that the Board of Government shall consider applications for membership with reference to the eligibility of each candidate for admission and shall determine the proper grade of membership to which he is entitled.

The Board must depend largely upon the members of the Society for the information which will enable it to arrive at a just conclusion. Every member is therefore urged to communicate promptly any facts in relation to the personal character or professional reputation and experience of the candidates which will assist the Board in its consideration. Communications relating to applicants are considered by the Board as strictly confidential.

The fact that applicants give the names of certain members as reference does not necessarily mean that such members endorse the candidate.

The Board of Government will not consider applications until the expiration of twenty (20) days from the date given.

For Admission.

ARMSTRONG, WALLACE EDGAR, Boston, Mass. (Age 31, b. Lebanon, Conn.) Graduate of University of Vermont with degree B. S. in civil engineering. From October 1916 to November 1917, valuation engineer with the Rutland Railroad Co.; military service, World War, April 1918 to July 1919; September 1919 to December 1920, assistant superintendent, Vermont Marble Co.; December 1920 to present time, junior engineer, U. S. Geological Survey, Water Resources branch, Boston. Refers to W. C. Eberhard, H. W. Fear, N. C. Grover, S. S. Kent, C. H. Pierce and M. R. Stackpole.

COOGAN, THOMAS PHILLIPS, Winthrop, Mass. (Age 24, b. Springfield, Mass.) Spent 1919-20 at Chauncy Hall School, 1920-21 at Mass. Institute of Technology, and 1921-22 at Lowell Institute. From January 1921 to date has been engineer for the National Waterproofing Co. Refers to W. F. Pike, H. C. Sheils, J. F. Travers, Jr., and H. C. Thomas.

LINDGREN, RAY HARRISON, Malden, Mass. (Age 28, b. Brookfield, Mass.) Graduate of the University of Maine, in civil engineering, with degree B. S., also post graduate course at Mass. Institute of Technology; 1916-17, structural detailer at the Edge Moor (Del.) plant of the American Bridge Co.; 1917-18, structural detailer and checker with the Lackawanna Bridge Co., at Buffalo, N. Y.; 1918-20, designing draftsman with Crandall Engineering Co.; and at present designing engineer with the same company. Refers to H. K. Barrows, H. S. Boardman, J. S. Crandall and H. C. Sheils.

RIVKIN, BERNARD MORRIS, Middleboro, Mass. (Age 27, b. Georgenburg, Lithuania.) Graduate of Baltimore City College in 1915; spent two years at Johns Hopkins University. From June to December, 1917, with Morris Knowles, Inc., as transitman on construction and town planning; February 1918 to March 1919, transitman and chief of party with Construction Division of War Department, and then transferred to accounting branch to analyze construction costs until October 1919; attended Mass. Institute of Technology October 1919 to June 1920; resident engineer, road construction, Mass. Department of Public Works, from June 1920 to October 1921; attended Mass. Institute of Technology from October 1921 to June 1922; and now with Mass. Department of Public Works. Refers to A. B. Appleton, A. W. Dean, H. F. Heald, H. F. MacWilliams, J. H. O'Connor and W. N. Wade.

ROBINSON, BLISS W., Boston, Mass. (Age 59, b. Shediad, N. B.) Spent four years' apprenticeship in machine shop and drafting room; ten years at sea, fireman to chief engineer; five years in Maryland and Fore River ship yards; seven years at boiler inspection; since January 1909 to the present time in charge main stations of main drainage and three substations, both steam and electric driven in use in pumping sewage. Refers to H. N. Cheney, E. S. Dorr, F. H. Fay, C. T. Main, F. A. McInnes, D. S. Reynolds.

THURBER, CLINTON DRAPER, Charlestown, Mass. (Age 45, b. Attleboro, Mass.) Graduate of Mass. Institute of Technology in civil engineering. Summers of 1896, 1897 and 1898 with Massachusetts State Survey as assistant

in field party on triangulation; summer of 1899 with Frank L. Fuller, in charge of topographical survey work; 1900-1902, draftsman in bridge department, Penn. Steel Co.; 1902-03 draftsman with Navy Department on structural design; 1904 to date commissioned officer in corps of Civil Engineers, U. S. Navy. Refers to H. B. Luther, C. M. Spofford, D. C. Webb and Ralph Whitman.

WELLS, EDWARD PIERCE, Malden, Mass. (Age 26, b. Boston, Mass.) Educated in the Malden schools and Lowell Institute. From October 1915 to November 1917 employed by Aberthaw Construction Co.; November 1917 to January 1919 in U. S. Army, Air Service; from January 1919 to date with Aberthaw Construction Co. Refers to A. B. MacMillan, J. A. Tomasello, L. C. Wason and F. S. Wells.

Transfer from Grade of Junior.

SMITH, MERRITT P., Waukegan, Ill. (Age 26, b. North Situate, R. I.) Graduate of Mass. Institute Technology. Experience as rodman with Miami Conservancy District in 1919; as junior engineer with the State of Illinois, 1919-1920; instructor at Mass. Institute Technology 1920-1922; resident engineer on highway construction with the State of Illinois 1922 to the present time. Refers to J. B. Babcock, C. B. Breed, D. Porter and C. M. Spofford.

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CHANGE OF ADDRESS.

FLETT, LOUIS E.....	27 Otis St., Medford, Mass.
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LIBRARY NOTES.

BOOK REVIEWS.

"DESCRIPTIVE GEOMETRY," by George Young, Professor of Architecture, Cornell University, and Hubert Eugene Baxter, Assistant Professor of Architecture, Cornell University. Edited by Dugald C. Jackson, Professor of Electrical Engineering, Mass. Institute of Technology. The MacMillan Co., N. Y., pp. 310.

REVIEWED BY WILLIAM H. LAWRENCE.*

Text books on descriptive geometry are almost as numerous as the teachers of the subject. The principles have been so thoroughly covered by existing texts that one wonders what can be the fascination which inspires the writer of a new book along these lines. To many students the subject has been a *bête noire*, not because of the intrinsic difficulty of its propositions which are in themselves simple enough, but because in addition to requiring close logical thinking, the orthographic methods of solution demand an ability to create in the imagination, a clear picture of the essential elements of the more or less abstract problems, and the ability to analyze and reason about them by means of this imaginary picture created in the subjective consciousness. This ability is not easy for every one to acquire, but in its accomplishment lies the greatest educational value of the subject.

The more concrete a proposition is made, the less effort will be required to create a mental picture of it. To an unimaginative student, for illustration, it is probably much easier to conceive mentally of a solid object of familiar form, than of an abstract line or an isolated point. Thus in many of the books published, the pure and comparatively simple fundamental propositions of descriptive geometry are served up with all sorts of condiments, in disguises intended to make them less distasteful to the mentally inert student, to enable him to obtain an apparent result with a minimum of conscious effort.

But if our assumption is correct that the value of the subject lies less in the material results obtained, than in the development of the imaginative power of the student, the mental effort is a necessary element in the accomplishment of that which makes

*Professor of Architectural Engineering, Mass. Inst. Technology.

the study worthwhile. To a student who is unwilling or incapable of making this mental effort, the study of descriptive geometry is distinctly not worth the time spent upon it.

Whether we start with a cube and conceive a plane as one of its faces, a line as one of its edges, and a point as one of its corners, or whether we start with the point and imagine that in movement it generates a line, that the line in movement generates a surface, and that surfaces enclosing a mass define a solid, the fact remains that the actual processes of orthographic projection deal directly with points, lines, and planes, and only indirectly with solids. The fundamental propositions of the science are based upon the point, line, and plane, and these once understood, form the basis of all possible applications.

It is on the whole, therefore, rather refreshing to find a presentation of the subject in which the authors, unafraid and with the courage of their convictions, develop the pure abstract principles clearly and simply before attempting the more complex applications.

Such a presentation is that in "Descriptive Geometry" by Young and Baxter, published by the MacMillan Co., 1921, in the Engineering Science series edited by Professors D. C. Jackson and E. R. Hedrick. In this book, the authors, after discussing the purpose and scope of the science on the basis that it underlies the language of drawing as the science of grammar underlies the language of words, proceed to give a very clear exposition of its fundamental conceptions and general laws. The first four chapters are devoted to a discussion of points and straight lines. In Chapter V the student is introduced to plane figures and simple solids and developments. The idea of projection on auxiliary planes is early introduced and finds numerous applications in the chapter. The representation of a plane by its traces is discussed in Chapter VI, followed by the usual fundamental problems involving relations between points, lines, and planes. Regular and freehand curves, conics, link-motion curves, and rolled curves are presented in Chapter VII; curved surfaces and intersections in Chapter VIII; Chapters IX, X, and XI include some forty pages of illustrations of applications to more or less practical problems. Chapter XII treats of shadows, and Chapter XIII

touches upon special methods of projection, such as perspective, isometric and oblique, and methods used in map making and topography.

Data for a number of exercise sheets to be solved by the student are given in each of the first eight chapters, and an appendix contains data for a large number of additional study sheets.

The scheme of the book is comprehensive and admirably carried out. It is logically arranged, very clearly written, and adequately illustrated.

It is to be regretted that so little use is made of the quadrants other than the first. This probably follows naturally from the facts that both authors are members of the architectural profession, and that most architectural problems are conveniently solved in the first quadrant; but it will render the book less interesting to the many who prefer third quadrant projection.

"ENGINES AND BOILERS," by Thomas T. Eyre, Dean, College of Engineering, State University of New Mexico, formerly Assistant Professor of Mechanical Engineering, Purdue University. Edited by Dugald C. Jackson, C.E., Professor of Electrical Engineering, Mass. Institute of Technology. The MacMillan Company, pp. 134.

REVIEWED BY EDWARD F. MILLER *

A book of about 235 pages prepared for use of students in technical schools. The book covers the subjects of fuels, combustion boilers and superheaters, boiler testing, boiler accessories, the steam engine indicator cards, valve design, governors, reversing gears, different types of steam turbines and the gas engine.

The book is well illustrated with line cuts.

Numerous examples showing the application of the formulae given are worked out in detail.

At the end of the book the author has given about ninety problems which cover the subject matter presented.

This book will be found to be an excellent text book for students studying civil engineering, chemical engineering or mining engineering.

* Professor of Mechanical Engineering, Mass. Inst. of Technology,

RECENT ADDITIONS TO THE LIBRARY.

U. S. Government Reports.

Annual reports U. S. Army, Chief of Engineers, Parts I and II, 1922.

U. S. Coast and Geodetic Survey, Special Publications, Nos. 74, 76, 77, 78, 79, 84 and 86.

State Reports.

Connecticut. Annual Report Public Utilities Commission, 1921.

Maine. Annual Report Public Utilities Commission, 1922.

New Hampshire. Annual Report Public Service Commission, 1921.

Municipal Reports.

Framingham, Mass. Annual Report Board of Public Works. 1922.

Mansfield, Mass. Annual Report of Town Officers. 1922.

Miscellaneous.

The Young Man and Civil Engineering. George F. Swain.

LIBRARY COMMITTEE.

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PAPERS AND DISCUSSIONS

This Society is not responsible for any statement made or opinion expressed in its publications

THE AMOSKEAG MANUFACTURING COMPANY HYDRO-ELECTRIC DEVELOPMENT.

BY ARTHUR T. SAFFORD,* MEMBER BOSTON SOCIETY OF CIVIL ENGINEERS.

(Presented January 24, 1923.)

WHEN the first good-sized modern water power development was built, and the now familiar features of concrete dam of heavy section, brick power house with steel skeleton frame, vertical water turbines set in reinforced-concrete scrolls, driving umbrella-type generators was written up, the description fitted, in a general way, most of the plants to be built at a later date until now; and where the different designs have worked out well in practice, they are generally accepted by engineers without question. This is true of the Amoskeag plant, recently built and running for the first time in the early part of 1923, which the author proposes to describe.

For this reason, and because of the mass of detail which makes up such a plant, it is difficult to make such a description interesting to one who is not familiar with the location, or has no personal interest in the company building the development, or in the concerns supplying the machinery or equipment, unless there are certain novel features which belong to this plant alone. Fortunately there are such features, and the history and circumstances of this re-development are somewhat unusual;

* Engineer, Proprietors of Locks and Canals, Lowell, Massachusetts.

and it will be the attempt of this paper to stress them as well as describe the principal structures and construction details in their order.

The features which are more or less unique with this development are:

The size of the textile mills served (some 800 000 spindles and 20 000 looms).

The remains on the site used for re-development of early cotton and other mills over one hundred years old.

The existing headgates, canals, waterways and waterwheels (50 in number), which are not to be scrapped but retained to run with surplus water.

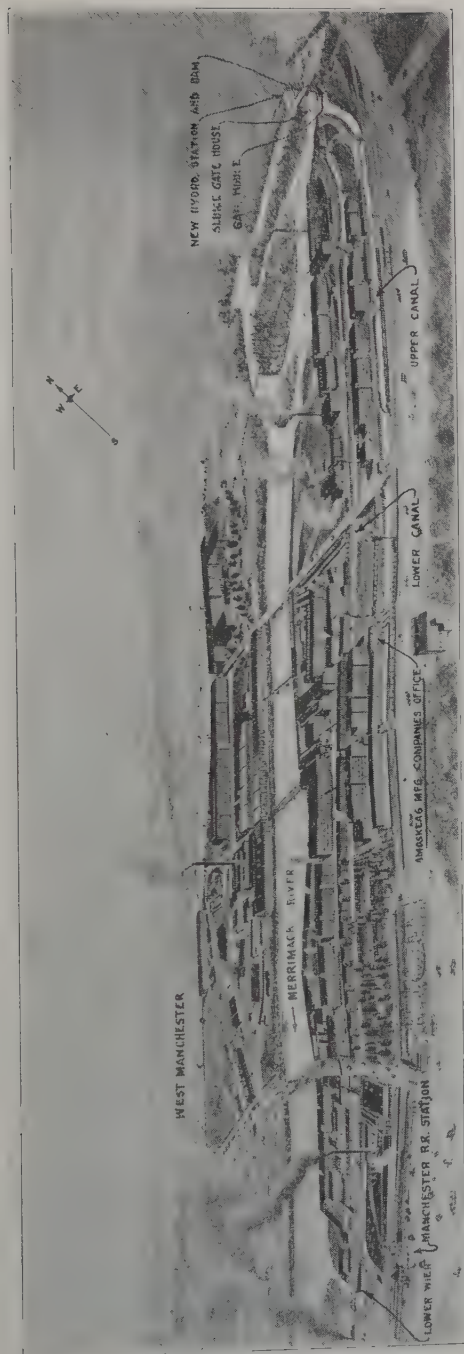
The eventual complete electrification of all of the power units of the Amoskeag Company, oil-driven, coal-driven and water power.

The connection with the neighboring Traction Company, which has already drawn 2 500 kilowatts on a Saturday afternoon from the new hydro station under a neighborly arrangement to give and take.

The flooding of a perfectly good, cut-granite masonry dam, which must be cut down to feed the new station properly and give the new dam a free flow at times of great freshet; the use of the west channel of the river as an overlarge canal; the cutting down of bars and a channel in ledge and gravel 200 ft. wide below the hydro station.

To use the old as far as possible and not duplicate, to design for an eventual complete use of the Merrimack River at Amoskeag Falls and Moore's Falls, eight miles below, and to build during two years of unusual flow with freshets coming about every month, have required not only very careful study and design on the author's part, but the closest attention on the part of the Amoskeag's engineers and superintendents, led by Mr. Perry Dow.

This re-development of the Merrimack River at Amoskeag Falls, Manchester, N. H., had its origin about 1918 in the minds of the treasurer, F. C. Dumaine and H. F. Straw, then agent of the Amoskeag Mfg. Company, when they asked the author of this paper to suggest how they might do their duty by the



AMOSKEAG MANUFACTURING CO. AND MERRIMACK RIVER.

Merrimack River. This is typical of the many instances in New England, where the seeds of conservation have fallen on fertile ground, already prepared by a growing interest in water power and increasing costs of coal and labor.

The study of a re-development at Amoskeag Falls went along with preliminary plans for developing Moore's Falls, eight miles below, because of the relation between the pond of the lower fall to backwater at Manchester. Many preliminary plans were made to show what might be done with one or more surplus power units of 1 000 h.p. or so each to be added to the Amoskeag Canal development of 1831, feeding something like fifty water wheels in twenty-seven groups; all these plans being finally abandoned for a new hydro-electric station, to use all the water during the lowest and average months through large modern wheels, thereby gradually making the present old wheels surplus-power wheels, to run at times of freshet and above the normal water.

The work begun in the early part of 1919 has been carried on fairly continuously, except for high water, particularly in 1919, until now, when two of the three 7 500 h.p. units are running, and show by their performance and the net head under which they are operating that they will develop well beyond their rated capacity. The power seems assured and it only remains to find out and remedy any defects in the appliances for operating — something which only the operating men will know.

EARLY DEVELOPMENTS AT AMOSKEAG FALLS.

The site of this new development, on the west channel of Amoskeag Falls, the earliest developments there and the subsequent canal developments on the east side about 1831, have so much historic interest that a description of these is essential to a complete story of the power at Amoskeag Falls.

There are three great natural falls of the Merrimack River at Manchester, Lowell and Lawrence, all developed for cotton and woolen manufacturing on a large scale, and known from the earliest Colonial times. A map called "Plat of Merrimack River from Ye See up to Wenepesoce Pond, also the corses from Dunstable (Mass.) to Penny-cook (New Hampshire) Jno Gardner "

and found among files of miscellaneous papers of Essex County, Mass., thought by the author to have been drawn previous to 1670, shows Amoskeag in its proper location between the Piscataquog River on the west below Manchester, and the Suncook River above and on the east.* The principal lake of the Merrimack drainage area, Winnipiseogee, is accurately shown and its latitude and longitude given.

The settlers of Massachusetts, particularly those living in Salem and Ipswich, were interested early in the 17th century in additional grants of land, and in their search for ship timber, the Merrimack River was an alluring highway for their raw material. Hence there were many surveys of this river and, later, many boundary-line disputes. Amoskeag Falls are mentioned repeatedly in these early records.

The origin of cotton spinning in New England early in the nineteenth century centers about the work and improvements of John Slater who settled in Pawtucket, R. I., and the power looms of Francis C. Lowell and Nathan Appleton, which were developed in Waltham and Lowell, Mass., about 1820, together make cotton manufacturing in New England already over one hundred years old. In 1810 there were 109 cotton factories in New England: Massachusetts had 54, New Hampshire 12, Vermont 1, Rhode Island 28, and Connecticut 14. Factories were started at Amoskeag Falls near the site of the new hydro station by Slater and others in 1810; and cotton mills have been operated in Manchester almost continuously since then. It is hard to imagine that a New England industry, one hundred and twelve years old, will be given up to southern competition without a struggle.

Just previous to 1800; the Proprietors of the Locks and Canals on the Merrimack River had built diversion dams and locks on the Merrimack River at Hooksett, Manchester, Goffs, Moore's and Cromwell's Falls, N. H., and Lowell, Mass., and navigation was open to boats and ship timber. The early canals of Manchester and Lowell were navigation canals, and remains of these and the locks are seen at low water in many places.

* The exploration of the Merrimack River, in 1638, by order of the General Court of Massachusetts, with a plan of the same, communicated by James Kimball.

In 1810 there was a mill and village called Amoskeag Village, already mentioned, on the west side of the river, and a saw-and-grist-mill nearly at the foot of the rapids of the west channel about where the stone crusher for the job was located; portions of the foundations of the mill and tailrace are either there now or have only been removed by the requirements of the new plant. The wheels were either overshot or tub wheels made by local millwrights and of small capacity.

In 1830 the Amoskeag Corporation had acquired all the rights to the land and water power on both sides of the Merrimack River at Amoskeag Falls and for a distance of a mile or more below, sold land and water power to the Stark Mills, and expected to sell mill sites and water power; but, having built and operated a mill of their own as early as 1831, went into manufacturing, gradually built mill after mill and enlarged their plant, until it now occupies in all about 140 acres and 6 000 000 sq. ft. of floor space in buildings on both sides of the Merrimack River.

The first water-power development at Manchester like those of Holyoke, Lewiston, Lowell, Lawrence, was by canals, which were located to make mill sites available with water power, the power being figured in "mill powers," so-called. A mill power was the water required to run an early mill, at Waltham, Mass., containing 3 584 spindles, spinning No. 14 yarn, with all the apparatus necessary to convert the cotton into cloth. This was taken as the standard for the mill power; in water it was the right to draw 25 cu. ft. per sec., on a fall of 30 ft., equal, according to James B. Francis, to about 60 h.p., for which the price fixed on was \$4 a spindle, or \$14 336 for a mill power and as much land as was proper for the establishment. As late as 1917, the writer remembers a mill of this type in Lowell, 145 ft. long and 45 ft. wide, one of the original three-story, hip-roofed factories, which still exist in some of the small villages in New England. A mill power was about eighty gross horse power, but with the type of wheel used, measured at the switchboard not more than fifty electrical horse power.

An interesting photograph shows the upper end of the 1831 canal system, the old wooden bridge at the head of the Falls,

headgates, lock and wasteway, and under construction, a sluice gate, to provide a means of sluicing water into the lower canal about where the old locks of the old navigation canal were located.

The upper canal of the development of 1831, supplying all the wheels except a few at a paper mill on the west side, was filled by six headgates of the four-leaf type, each one controlled by power from a water wheel in the headgate house, but with



OLD DAM, GATEHOUSE AND AMOSKEAG COVERED BRIDGE.

steam engine and, later, motor auxiliary. These gates are not a rare type, but not as common as the single, big, straight-lift type, seen in every water-wheel catalogue. They have given good service through fifty years and will be continued in a new brick gatehouse built around the wooden one, but will be individually motor-driven. The gates are of 10 x 10 ft. clear opening or 100 sq. ft. each.

The water-power structures at that time were well and solidly built and have required little or no renewals. The masonry was usually granite of the best kind and the wood used, usually oak. The racks in the canals, heavy headgates, masonry flumes, pits, and tailraces are a part of the very structure of the mill yard and will remain unless filled up.

The Amoskeag offices are full of records, photos and relics of the early millwrights, masons and machinists who, out of their training built a wooden flume as they would a ship, a wheel pit as if it was their own tomb, and set wheels, gears and shafting plumb or level, as required, on foundations which did not vibrate. The same men in the shops which were a part of the great plant known as the Amoskeag, built machinery, locomotives and fire engines which in their day were as well-known as the company's cloth products.

The old wheels are arranged in groups, some drawing water from the upper level, some from the lower, and one group, the Jefferson wheels, drawing water from the upper canal, through penstocks under the lower canal and discharging directly into the river. This is a horizontal-wheel plant well designed and of the best type of horizontal end discharge wheels of twenty-five years ago. Tests of the efficiency of these old wheels show at the switchboard an efficiency varying from more than 50 to 75 per cent. of the gross power of the water. The final result from the new hydro plant will be a more efficient use of the low and normal flow of the river, in gain perhaps one-third, and the new use of more water than the total used prior to 1923.

The names of the old wheels "picker wheel," "number 4," "Jefferson Mill," etc., suggest the original purpose of each wheel. The canals were built as they were, and as far apart as they were, to provide mill sites, and each wheel, or group of wheels, drove a mill or mills. Formerly these wheels and the engines of twenty years ago were connected through heavy shafts; and although everything was of the best design for the times with self-oiling devices everywhere, the shafting load must have been enormous, probably nearly as large as the lowest water power of the Merrimack River at this fall, during droughts like 1883, 1894 and 1911, when either Winnipiseogee Lake was about drawn out or the extreme cold of the winter had frozen up the tributary streams.

A good cut-granite masonry dam, built in 1871, located down stream and taking the place of an older dam, carried the freshets safely for fifty years, except for a few capstones, which were worked loose by the frost and ice and replaced by others

which were dowelled to the stones below. The loss of cement and subsequent filling-up of the joints with vegetable matter, appears to have made the top course subject to sliding from ice and water pressure. Some of these capstones were found in the potholes below the dam and were used by us to break the joint between the foundation and section above the bottom of the new dam. The old dam was of two parts, a curved section 420 ft. long, and a



GATEHOUSE AND HEAD OF CANAL OF 1831 SYSTEM.

straight section parallel with the river 260 ft. long, a total length of 680 ft., but not all effective in a very great freshet because of the channels below.

The six headgates of the 1831 canal have been mentioned. A broad channel below the headgates where the canal is about 120 ft. wide, led to waste weirs and a gate feeding the lower canal. The upper canal about a mile long and 60 ft. wide and a lower canal parallel with it fed the mills and wheels.

Altogether there were not only 50 wheels in 37 groups, but as many headgates, penstocks, tailraces and other machinery necessary for their operation. The average rating was about 300 h.p. to each unit, but one group, the Jefferson, which op-

erated under the full fall by water brought from the upper canal under the lower canal, developed upward of 1 200 h.p. The units in the new hydro station are rated at 7 500 h.p. each, and two of them will develop just about as much power as all the old wheels together. It is intended that some of the old wheels will continue to run until the mills are entirely electrified and all of them with surplus water until worn out. The last 10 per cent. will probably be electrified within the next five years.

In point of transmission, the Amoskeag Mills have been so nearly electrified for years; and its steam and water power units so interconnected, that the building of the hydro station found a system to tie into, which had been already planned. The main-steam units in the northern and southern division and the station across the river where the Coolidge Mill is located, were all connected together and power could be transferred almost at will, and at times power was drawn from or pumped into the Traction Company's wires which cross the river below the new hydro station. In connection with the new work, however, a central station has been built with lines coming from and radiating to every source of power and use. In addition to the present generating units, provision has been made for lines from Moore's Falls, eight miles below, which may be developed if coal remains high and New England prosperous.

The Amoskeag has about 600 000 cotton and 200 000 worsted spindles, and 20 000 looms driven by the combined-power load of 40 000 h.p. of all kinds or 5 h.p. to the spindle. Its coal consumption had been upward of 100 000 tons annually but with the use of oil at the northern division and the new hydro station, this amount will be cut down very materially. The success of the fuel-oil installation and the increased use of water power as measured by savings of coal are now very much in the minds of the management.

The Amoskeag, however, has led in electrification among the older mills, and the building of the new plant found the mill about three-quarters electrified with synchronous generators on the main shafts to take up the slack. The few water-power units of the old development will be gradually electrified but only run with surplus power.

The company had a maximum water-power output of about 15 000 h.p. with a minimum of about 5 000 h.p., engine capacity of about 40 000 h.p., and boiler capacity of 10 000 h. p. more than this for steam and process purposes. There are three main divisions of steam power, the northern, central and southern divisions, all electrified.

There was very little cheap electric power in large blocks available from outside sources which the Amoskeag might have contracted for; the ordinary price for blocks of approximately 1 000 kilowatts appeared to be about 1.6 cents per kilowatt hour or \$45 per kilowatt for the textile year of 2 800 hours. Steam power can be made at the Amoskeag for about this figure so that any new water power must compete with steam power at this price. The Amoskeag have an arrangement by which, for a price, they can give and take power from the Traction Company which in time will probably take all the available power from the river which they cannot use themselves, which is upward of 40 000 h.p. when the mills are running full. There is no question, therefore, of a market for all the water power which the river will furnish.

DRAINAGE AREA, STORAGE AND FLOW.

Some reference to the drainage area, water storage and flow should be made. The area contributing to the Merrimack River above the Amoskeag dam is 2 839 sq. mi.; most of it from large tributaries, the Pemigewassett, Contoocook with little or no storage, and several, the Suncook, Winnipiseogee and Squam, with some or most of the area under control. The annual precipitation, measured for the most part by gages in the valley, is about 42 in., but varies from 33 in. in an extremely dry year like 1911, to 52 in. in a very wet year like 1890. A few gages, recently installed, show for higher altitudes (approximately 1 200 feet) precipitation 20 per cent. in excess of the annual record of 42 in. The general slope of the hills and mountains is towards the south, which means an early freshet and occasional heavy flood earlier than the normal April flood. The greatest freshet of recent years, March 2, 1896, was caused by rain and snow on frozen ground. In amount, this was 87 000

sec. ft. on the 4 085 sq. mi. above Lowell and 60 000 sec. ft. at Manchester, or about 20 sec. ft. per sq. mi. It is evident from the height at the Manchester and Lowell dams and the slope of the river between Manchester and Lowell, that the quantity per square mile passing the two points in the two cases is not very different.* Measuring stations are maintained at Plymouth, N. H. (Pemigewassett River), Lake Village on Lake Winnipiseogee, N. H., and Franklin, N. H., below the junction of the two rivers. Any great freshet or holding back of the water is known by these gages a day or two ahead of its being felt at Manchester. The discharge into the main river at Franklin from the two branches is practically a 24-hour flow except for Sunday shutdowns; the use at Sewall's Falls above Concord, N. H., and Garvin's Falls below Concord, N. H., is a long public-service day of practically sixteen hours; the development at Hooksett is relatively small, with waste over the dam most of the time, so that the flow into the Amoskeag pond is fairly uniform, but its capacity, 43 000 000 cu. ft. with 3 ft. drawdown, is not sufficient to store all the night flow.

A map of the drainage area of the Merrimack River and other rivers in New England shows the Merrimack at its mouth to have about 4 500 sq. mi., or about the size of the Androscoggin and Kennebec, and the Connecticut at Vernon, N. H., but not as large as the Penobscot, or Connecticut at Turners Falls. Unlike the Connecticut, it has one large storage reservoir in Lake Winnipiseogee, which with some neighboring lakes, contains about ten billion cubic feet; it has not the storage of the Kennebec in Moosehead Lake (about twenty-three billion) or the natural and artificial reservoirs of the Androscoggin which contain altogether about thirty billion cubic feet. The Merrimack above Manchester, N. H., however, has a great freshet storage over the Concord meadows so that the peak of any freshet is fairly well lengthened out.

The extremes of freshet and drought at Manchester are from 60 000 sec. ft. to about 800; the snowfall, particularly in the upper valleys and on the hills, is heavy, varying from 40

* The average slope between dams in a great freshet like 1896 is almost always something approaching 1.5 ft. to the mile.

to 100 in.; the ice breaks up occasionally when hard and thick, subjecting every structure to the hardest kind of usage; but, with the old and new development, it will be possible without further storage, to put to work about 50 per cent. of the total run-off of the stream above Manchester.

The amount of storage above Manchester is about ten billion cubic feet, most of which is in Winnipiseogee and good for about 500 sec. ft. 24 hours in the day, in the addition to run-off from the unstored area. Plans are being developed for a possible increase in storage amounting to another 10 billion cu. ft. but it will be very expensive.

The mill pond above Manchester contains about forty-three million cubic feet with 3 ft. drawdown, or just about enough to store 1 000 sec. ft. for twelve hours or 1 500 sec. ft. for eight hours, equal to a concentration factor of perhaps two at low water against three at Lowell and Lawrence. As the Amoskeag, however, have and probably will run a part of their mills nights to use the night flow, there is very little loss of water because of the relatively small capacity of the mill pond, but it should be increased.

The most severe tests of a water-power development come from the great freshets like that of 1896, when the head water rose 11 ft. and the backwater about 20 ft., from anchor ice in the early winter and the extremely heavy ice in the spring when the river breaks up in March instead of April, and the severe winter droughts like that of 1911-12, and threatened for 1922-23, when the streams are ice-bound and the canals freeze several inches* thick over nights and Sundays.

From the junction of the Pemigewassett and Winnipiseogee Rivers at Franklin which form the Merrimack, there is about 250 ft. fall, about three-quarters of which is used in the public-service plants at Sewall's Falls, Garvin's Falls and Hooksett, and the textile cities of Manchester, Lowell and Lawrence. The Merrimack turns more cotton spindles than any river in the United States, and we hope will continue to do this.

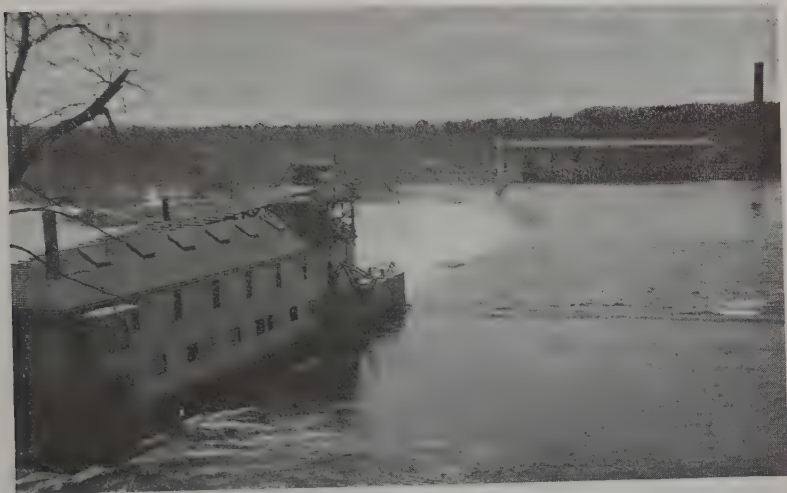
I have gone into the early history and detail of the early and 1831 development of water power at Amoskeag Falls so

* Ice $3\frac{5}{8}$ in. thick in one continuous freezing at Lowell from February 17 to 19, 1923.

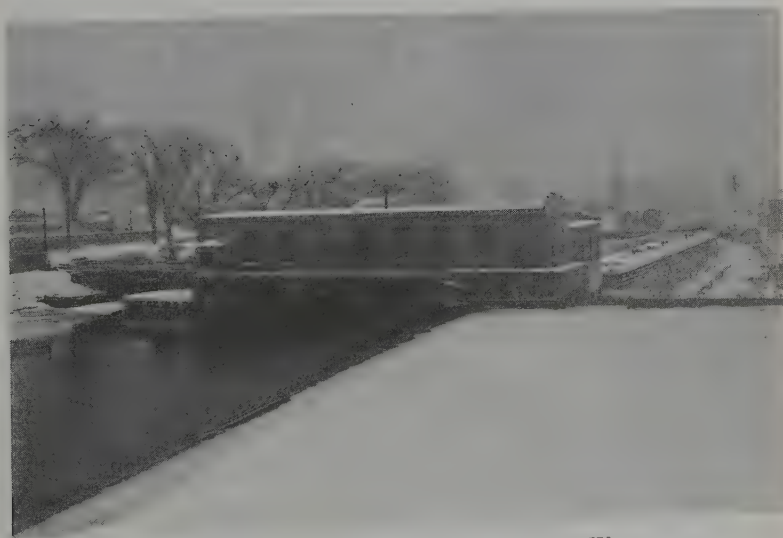
thoroughly because it was so well done, and has given a reasonably good efficiency through nearly one hundred years of cotton manufacturing, during the first part of which there was but one kind of power. As the mills grew and gradually got to require the 40 000 to 50 000 h.p., it was evident that there should be a large development of steam, which would perhaps have been sufficient had coal remained cheap, but war conditions and \$10 coal were more responsible for the re-development of the water power than the need of more power.

The problem given to the engineers was to use the present dam, or build a new one, construct a new canal, station and install turbines which should, as far as is possible, develop the full capacity of the generators (5 000 kilowatts at 0.8 power factor) under all conditions of water, on a stream which is subject to sudden rises, protracted droughts and where water storage so far built is but one-tenth of the total run-off. The total fall from the top of the old dam to the river above the Macgregor bridge at times of low flow is over 50 ft.; formerly the head was reduced by headgates during freshets and the backwater raised from a few feet to 20 ft.; the design of the new station and digging out of the tailrace will bring the water at all heights directly to the station, and the backwater, relatively, will be much less of a handicap as it comes out of one fall instead of two.

The new dam floods the dam of 1871, which will be cut down a few feet in order to eliminate any loss of head over it. The headgates on the east side will remain to feed the canal and wheels during times of surplus water and the new sluice gates which are located on that side of the river. The old locking gates have been renewed with stronger-lift gates to help out the sluice gates which will have a capacity of about 4 000 sec. ft., and enable the flashboards to be retained with less chance of loss and labor. It is proposed to increase the Manchester pond, particularly in the winter, by additional flashboards, if arrangements can be made. The writer finds, with any mill pond frozen, it takes an extra foot or two of pondage to make good the reduction of area by the ice freezing along the slopes of the shores of the river.



OLD GATEHOUSE UNDER RECONSTRUCTION, NEW DAM WITH SPRING FRESHET,
NEW HYDRO STATION.



OLD GATEHOUSE REBUILT AND OLD CANAL WALL.

RE-DEVELOPMENT OF AMOSKEAG FALLS.

Many sites were studied for the re-development. With the idea that any re-development might be simply for surplus power, there were a good many locations on the east side, where additional power could be generated at a comparatively low cost,



SITE OF NEW HYDRO STATION, CONSTRUCTION EQUIPMENT, NEW DAM
NEARLY FINISHED, WIRE TUNNEL.

— simply that for the new equipment, wheels and generators and the settings; but it was found that where the canal of 1831 was large enough, the river bed was high, and where the river was lower, the canals had already been overtaxed in capacity. The very old development at the Cheney Paper Mill, in 1918 leased to a Hosiery Mill, on the west side of the west channel, led to a study of this location; here, however, the head was relatively low (about 30 ft. out of 50 ft.), and the channel was likely to be flooded at times of freshet.

A canal from above the dam on this side, under the street (Amoskeag Bridge), and dug through Amoskeag Mill Village to

the foot of the west channel was seriously considered; but all these locations were finally given up for the plan selected, which made of the west channel a canal, cut off the west channel by the new hydro station and spillway dam up-river, and across to the present old gatehouse on the east side.

Work began in the fall of 1919 but the equipment, turbines, generators, governors, headgate hoists were not ordered until spring of the following year. High water and the textile strike of 1922 added several months each to the length of the job, but otherwise it was continuous until finished in the late fall of 1922. The old dam is drilled, ready to lift off the top stones and clear the way to draw the millpond down behind the new dam. But two units were installed, but speed ring and pit liner have been set for the third.

The work was handled by the Amoskeag organization by day labor, which was increased in certain directions to meet the requirements of a job of this size, and some new machinery, particularly rock crushers, compressed-air drills for rock excavation, and steam shovels for the tailrace work were purchased in addition to other equipment which was on hand. Work was going on at different points in the dam and power house at the same time; and foundations were built and oil tanks erected during the progress of the work on the station and dam.

In amount the dam does not contain more masonry than the foundations for the Coolidge Mill built in 1912, and the Amoskeag organization had built foundations and installed hydraulic, mechanical and electrical machinery for years.

The amount of material and equipment bought and figures of excavation, concrete, etc., are given as a matter of record.

I. Dam	
Mass concrete.....	16 000 cu. yds.
Rock excavation.....	4 000 cu. yds.
II. Removal of Top of Present Dam	
Masonry removed.....	1 000 cu. yds.
III. Power Station Foundation	
Mass and reinforced concrete.....	23 000 cu. yds.
Steel reinforcement.....	400 tons
Structural steel, racks, etc.....	100 tons
Rock excavation.....	8 000 cu. yds.

- IV. Power Station Superstructure
 - Volume of building..... 670 000 cu. ft.
 - Structural steel..... 160 tons
- V. Hydraulic Equipment. Complete Installation.
 - 3 I. P. Morris turbines, each 7 500 h.p.,
maximum at 46 ft. head, using 1 700 c.f.p.s.
 - 3 65 000 ft. lb. Woodward governors complete with Central Pumping System.
 - 9 10 ft. × 20 ft. wooden gates with steel stems.
 - 9 motor-driven gate hoists, each 60 000 lb. capacity.
- VI. Electric Equipment. Complete Installation.
 - 3 6 250 kva. General Electric Co. A. C. generator, 5 000 kw. 0.8 P.F., 2 300 volts, 3-phase, 60-cycle, 112.5 r.p.m.
 - 3 200 kw. motor-driven excitors.
- VII. Miscellaneous Equipment
 - 1 60-ton Northern crane, with two 30-ton hoists, 51 ft. — 10 in. spans.
- VIII. Tailrace
 - Rock excavation..... 7 000 cu. yds.
 - Excavation (other materials)..... 100 000 cu. yds.
- IX. Sluice gates — cutting out masonry, gates and hoists.

DESIGN AND CONSTRUCTION OF DAM.

The dam is in two parts, one stretch 400 ft. long at El. 72 from the power house up-river, and the rest 340 ft. long at El. 70 from this point to the old gatehouse, which has been reinforced by a new abutment facing up the old to El. 82 or 12 ft. above the crest of the upper stretch of the dam at El. 70. It is expected that 2- and 4- ft. flashboards will be maintained on the new dam bringing the structure during low and normal stages of the river to El. 74. The section of the dam is of solid concrete, excepting the cable and inspection tunnel, and compares well in weight and stability with the other dams on this and the Connecticut Rivers.

Where the dam is 25 ft. high the bottom is about 25 ft. thick and every part of it, even the foundations in the deep pot-holes on solid ledge, was roughened up by drills and grouted before the first concrete was poured. The dam has a 1- to 4-slope on the upstream face and an "ogee" shape for the down-

stream without any kickup at the foot of the dam. The rock is a granite, very hard in character, but covered with much loose material excepting where the water had washed over it during years of freshet. The slope of the bottom of the west channel in a state of nature was considerable; and, where the rock ran

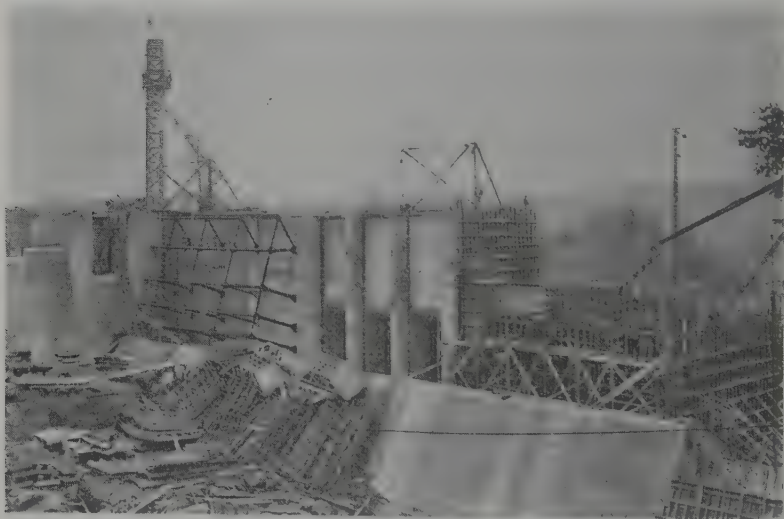


ICE GATE, NEW DAM COMPLETE, OLD GATEHOUSE REBUILT.

out below the power house, the bottom was about thirty feet lower than the ledge forming the bottom of the river at the east end of the dam. The dam was built with derricks and skips, the material being carried to derricks by a small industrial railroad from the mixer which was located near the crusher. The material used was a mixture of the local rock crushed and material hauled to the job from local sources. Sand was local and of good quality. Several brands of cement were used, much of it in bulk, due to the difficulty at the time of getting the cement in bags. Much of the concrete was poured in very cold weather, and the last section when the thermometer was twenty degrees below zero. The forms were well made, and, in cold weather, the materials heated and steam introduced and kept

up for several days after the pouring. The particular section 40 ft. long, poured during the coldest weather, by observation inside the tunnel is perhaps the driest of all the sections. Application was made the Public Service Commission of New Hampshire to build this dam under the following law:

"No person shall begin the construction of any dam in this state until he has filed with the Public Service Commission a statement of the height of the proposed dam and of the location at which it is to be erected. The Commission shall thereupon make investigation, and if after notice and hearing it shall find that said dam, if improperly constructed, would be a menace to the public safety, said dam shall be in all respects subject to the provisions of this act in the same manner as dams of a height in excess of twenty-five feet."

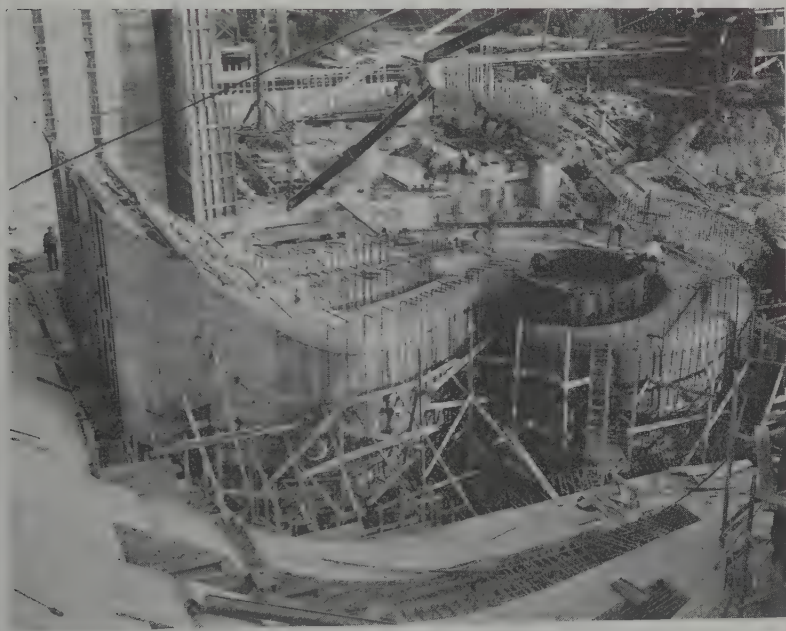


RACK DAM, PENSTOCK ENTRANCE TO NO. 3 UNIT, CONCRETE TOWER
AND CHUTE.

No objections were made to any of the designs or plans and it is assumed that the structure is satisfactory to them.

The rack dam at El. 52 which forms the lowest cut-off, is continuous across the west channel and bonded into the ledge on both sides. It is of solid concrete and dowelled to the ledge

under it. The racks, headgates and hoists are of regular design, but the hoists are motor-driven and the gates covered by the roof of the power house. The scrolls are of concrete with thin, tapering partitions, three each 10 ft. wide x 20 ft. high, and conform to the measurements which the I. P. Morris Company specified.



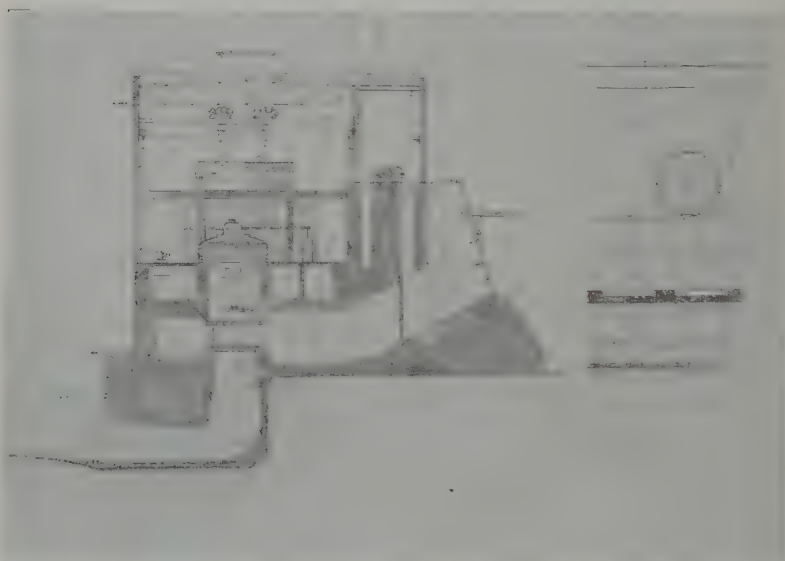
SCROLL FORMS FOR No. 3 UNIT.

POWER HOUSE.

The power house is of brick, approximately 200 ft. long x 65 ft. wide, and 62 ft. high above the generator floor at El. 61. The height of the building in the clear was fixed by the lift of the motor-driven crane, which lifts 55 ft. from the generator floor. The draught tubes at El. 17.25, the center of the wheel openings at El. 40 and the top of the generator at El. 73 are all fixed by the division of practically fifty feet fall into the requirements of each 5 000 kilowatt unit. The foundations of the power house,

wheel settings, penstocks and draught tubes are of concrete; the power house of skeleton-steel frame and brick on concrete foundations; the roof of concrete supported by steel girders and covered with tar and gravel.

The power house is at right angles to the new dam and is on foundations which are on the same granite ledges as form the foundation of the new dam. Because of the width of the west



PLAN AND SECTION THROUGH NEW HYDRO STATION AND ONE COMPLETE UNIT.

channel at the site of the hydro station, it is longer than is necessary for the three units, switchboard and the different auxiliaries; but as the branch railroad track on the west side led directly to the old boiler house of the Cheney Mill and could be extended directly into the station, there was no particular advantage in making the station less than 200 ft. long. There is one intermediate floor or basement at the level of the turbine gates. This basement will be used for storage and carry incoming transformers from the Traction Company's 30 000 volt current and outgoing 2 300 volt current into the Coolidge Mill and to the tunnel in the dam.

The west end of the power house opens to receive a standard-gage track and unloading platform within reach of the crane. The rack dam, which is the lowest cutoff, the scrolls, wheel chambers, and draught tubes are all shown on a sketch plan and section through one unit. The spacing of two wheels in the westerly half of the power house and one in the easterly half, to take advantage of a rock island in the west channel, gives an appearance of solidity to the station in addition to the materials used.

The generator floor is reached by easy stairs from the basement and, eventually, from a gallery at the track level from the main doors at the west end of the station.

The turbines are the I. P. Morris type 0 with all the improvements in gate mechanism and governing which this company and its subsidiaries offered. The rating is 7 500 h.p. at 112.5 r.p.m. with 46 ft. head. The design of scrolls and draught tubes with some few exceptions, were submitted by them, and their guarantee of 89 per cent. for the turbines in place is sufficient warrant for their good behavior. The generators were built and furnished by the General Electric Company under an efficiency guarantee of 95 per cent. at 0.80 power factor. Under the early conditions of fall and flow which are not yet as good as can be obtained, one machine has already developed for a short time as high as 5 900 kilowatts at .90 gate. Current is generated at 2 300 volts and the ordinary mill loads will be carried without transformers.

The switchboard is carried on a mezzanine floor on the east end of the power house. The work of casting the cells of sand and cement grout was unusually well done, and the provision for easy access and operating of the best.

The fall from the crest of the new dam at El. 70 to tailwater below the Macgregor Bridge when the mills are shut down and very little water is running is fifty feet or more. Between the Macgregor Bridge and the new hydro station were a number of bars of ledge and gravel which altogether used up about ten feet. The station was designed originally for 46 ft. head, with draught tubes at 17.25 and tailwater at El. 26 when all three units are running. The company controls an undeveloped power at

Moore's Falls, 8 miles below Manchester and the height of this dam has been tentatively fixed at 16 and flashboards at 24. To get the rest of this fall nearly down to the top of the proposed Moore's Falls flashboards, it was necessary to blast and clean out a channel 200 ft. wide with its bottom at 19 for a distance about 1 000 ft. below the new station. The material moved



REAR OF NEW HYDRO STATION AND TAILRACE.

about 100 000 yards with steam shovels, trucks and teams to a dump just outside of the tailrace, occupied most of this last summer and fall when the water was low. A cut-off wall was built across a portion of the middle channel to prevent the water at times of ordinary freshets from coming into the tailrace of the new hydro station.

The following contractors supplied machinery or equipment:

General Electric Co. — generators, switches, switchboards, etc.

The I. P. Morris Company — turbines.

Woodward Governor Company — governors.

Northern Electric Company — 60-ton crane.

Shoemaker Sutterthwait Bridge Company — structural steel.

Detroit Steel Products Company — window sash.

Except for cutting down the old dam, the work was completed by January, 1923.

The description of this power plant, published in cold print, even with illustrations, makes dry reading and is not to be compared with the growth on the site. It would take a moving picture of the excavation and construction as they proceeded day by day to show the growth of the dam and power house from the comparatively few yards of concrete to fill up the holes in the foundations, to the best day's run of several hundred yards of concrete (to be beaten later by a better day's record) and so on to completion, when the river could be ignored and the brick laid up as if on solid ground.

CAPACITY OF NEW PLANT.

The output of the 1831 and later developments, up to the building of the new station is somewhat doubtful, but can be estimated approximately.

On May 20, 1921, the "total water power" from the mill records was:

At 8 A. M.....	15 439 h.p.
11 A. M.....	15 374 h.p.
2 P. M.	15 214 h.p.
4 P. M.	15 310 h.p.
An average of	15 334 h.p.

which may be considered a maximum.

The flow at Lawrence, Mass., for the month of May, 1921, proportioned to the drainage area above Manchester, N. H., was 5 560 sec. ft. 24 hours in the day, or a little more than that required for all the wheels at Manchester, but without much backwater; all of which bears out the fact that this day is probably about a maximum day.

On September 13, 1921, the "total water power" from the same records was:

At 8 A. M.....	8 522 h.p.
11 A. M.....	7 527 h.p.
2 P. M.	6 664 h.p.
4 P. M.	7 112 h.p.
An average of	7 456 h.p.

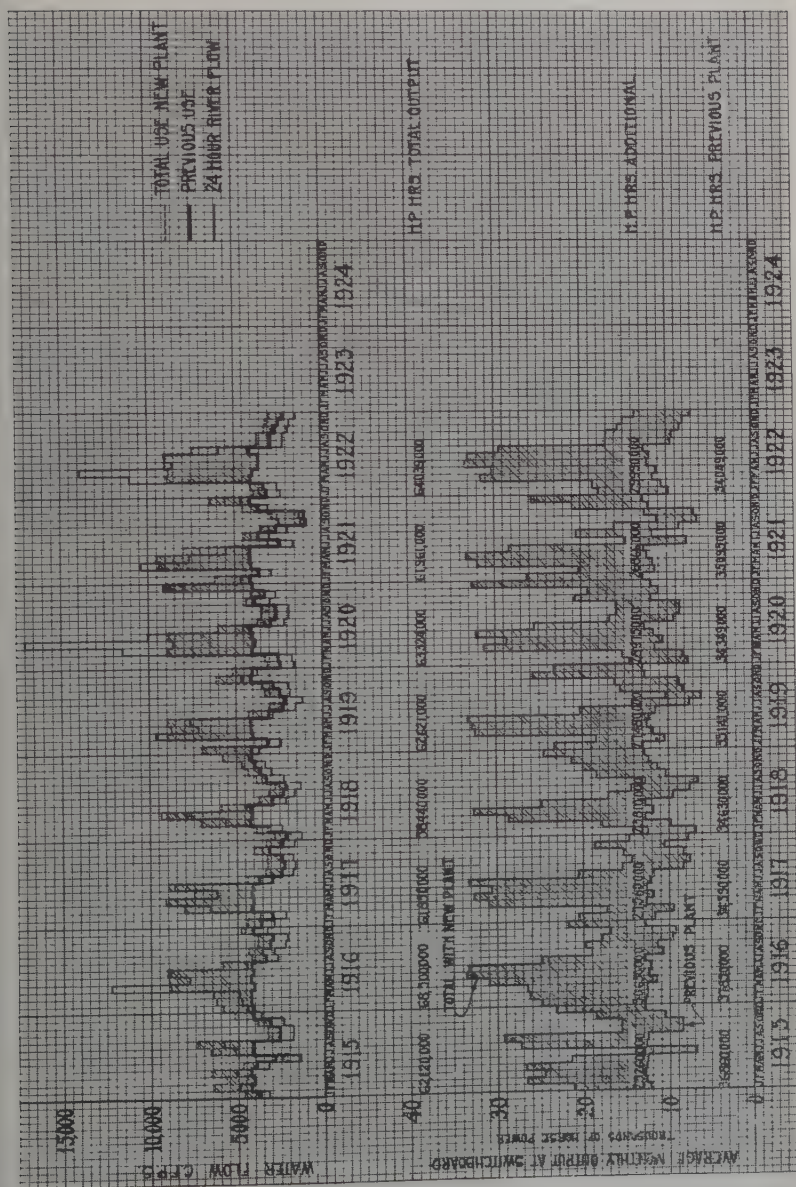
If the Amoskeag got, as a rough average, 6 months at 15 334 h.p. and 6 months at 7 456 h.p., the yearly average would be 11 395 or 31 906 000 h.p. hours in the year. Adding to this, night running by the Jefferson wheels of something like 1 200 h.p. for 3 000 hours may have produced an additional 3 600 000 h.p. hours which added to 31 906 000 makes a total of 35 506 000 for the year.

Based upon the flow for four years preceding the building of the new hydro station, and the pondage, headwater and tail-water as they were and are expected to be, when both the new station * and this and the old wheels are running, the following figures are my estimate of the output:

Year.	From the Old Wheels. H.P. Hours.	From the New Hydro Station. H.P. Hours.	Total from the New and Old. H.P. Hours.
1915	36 860 000	25 260 000	62 120 000
1916	37 850 000	30 650 000	68 500 000
1917	34 390 000	27 560 000	61 850 000
1918	34 630 000	23 810 000	58 440 000
1919	35 141 000	27 480 000	62 621 000
1920	34 349 000	28 975 000	63 324 000
1921	35 095 000	26 866 000	61 961 000
1922	34 049 000	29 990 000	64 039 000
Average	35 295 500	27 573 875	62 856 875

The flow of the Merrimack River at Manchester, N. H., based upon the figures for Lawrence, Mass., but proportioned to the drainage area of 2 839 sq. mi. above Manchester for the 42 years from 1880 to 1921, averages 4 165 sec. ft. during 24 hours in the day. During the eight years 1915 to 1922, the corresponding flow averaged 4 343 sec. ft. about 4 per cent., more than the average. With the period picked about the average, and the stored water all passing Manchester instead of being proportional to the respective drainage areas, it is fair to assume that the figures given, 62 856 875 h.p. hours, are pretty apt to be realized from 2 units and an additional 6 000 000 h.p. hours with 3 units running. In kilowatt hours this means in round numbers 50 000 000 kilowatt hours in an average year.

* Two units now installed and running.



AMOSKEAG MANUFACTURING CO. — POWER OUTPUT OF WATER WHEELS

During the period from 1911 to 1914, however, the flow of the Merrimack River was very low; and a repetition of years like these will cut the output materially. By ten and five year periods the figures for Lawrence are as follows: *

Ten years	1881—1890.....	1.62 sec. ft. per sq. mi.
Ten years	1891—1900.....	1.52 sec. ft. per sq. mi.
Ten years	1901—1910.....	1.45 sec. ft. per sq. mi.
Five years	1911—1915.....	1.21 sec. ft. per sq. mi.
Five years	1916—1920.....	1.52 sec. ft. per sq. mi.
Forty years	1881—1920.....	1.49 sec. ft. per sq. mi.

As the rainfall after all is the principal element making up the flow, a comparison of the rainfall during this eight-year period from 1915 to 1922, and the longer period from 1881 to 1920 with that for a much longer period, will give a very fair idea of how permanent is this flow. A study of a diagram from X. H. Goodnough's Paper on "Rainfall in New England" (*Journal of the N. E. W. W.*, September, 1915, Plate XXII, continued to 1920) shows about fifteen low periods in one hundred fifty years, but as many high ones, so it is fairly safe to conclude that the Merrimack River at Manchester, N. H., and other New England rivers will continue to furnish about the same amount of raw material for use as before.

Yearly averages are sometimes misleading without large storage and pondage but the difference between the result from an average yearly flow and the average of the different months from the lowest up, to the output of the equipment installed has all been discounted in the figures given above, and no dependence, as yet, has been placed upon the relatively high figures of run-off for the Merrimack at Franklin Junction, Garvin's Falls, and the Pemigewassett at Plymouth.† The total water requirements for all the wheels at Manchester, new

* From Report of Committee on Run-Off, JOURNAL BOSTON SOCIETY OF CIVIL ENGINEERS, October, 1922. Appendix A.

	Second Feet per Sq. Mi.	
† Pemigewassett River at Plymouth, N. H.....	2.21	1903—1922.
Merrimack River at Franklin Junction, N. H.....	1.93	1903—1922.
Merrimack River at Garvin's Falls, N. H.....	1.63	1904—1916.

Biennial Report of the Public Service Commission of New Hampshire. Advance copy, pages 28 and 29.

UPPER LEVEL		CFPS	M.P.
1 PAPER MILL	1 HERCULES	77.49	2.4
2 LANGDON	2 HERCULES	306.67	8.53
3 AMORY	4 BOYDEN	856.40	23.60
4 STARK MILLS	1 "	107.71	2.87
5 "	2 "	312.54	8.65
6 "	1 "	TAKEN	OUT
7 "	2 "	305.09	8.44
8 AMOSKEAG NO. 1	2 HUNT	253.75	7.10
9 "	3 BOYDEN	401.78	11.23
10 "	2 "	166.41	4.65
11 "	3 HUNT	264.21	7.44
12 "	1 BOYDEN	188.09	5.30
26 JEFFERSON MILL	4 HERCULES	714.26	45.16

LOWER LEVEL		CFPS	M.P.
13 PUMP HOUSE	1 BOYDEN	65.26	1.80
14 JEFFERSON MILL	2 HERCULES	268.77	9.42
15 STARK PICKER	2 PRS.	374.60	13.42
16 AMOSKEAG NO. 9	3 BOYDEN	729.15	28.77
17 AM. MACHINE SHOP	1 "	127.99	4.98
18 AMOSKEAG NO. 7	1 "	NOT USED	
19 "	NOS. 4 & 5	1 BOYDEN	TAKEN
20 "	"	2 HERCULES	OUT
21 "	"	2 "	373.70
22 "	NO. 1 SO.	2 "	373.70
23 "	"	2 "	492.54
24 "	DYE NO.	1 RISDON	492.54
25 "	P.W.	2 HERCULES	TAKEN

LOWER LEVEL		CFPS	M.P.
27 AMOSKEAG NOS. 4 & 5	1 BOYDEN	136.56	535
28 OLZEDAM MILL	1 "	TAKEN	OUT
RIVER			
29 HYDRO ELEC. STA.	3 I.P. MORRIS	5100	



GENERAL PLAN OF OLD AND NEW WATER POWER SYSTEM, AMOSKEAG MANUFACTURING CO.

and old, will be about 9 000 sec. ft., which will mean a 24-hour flow of 7 500 sec. ft. of water; and, for the new plant 5 100 sec. ft. (three units), and old 3 600 sec. ft. The 7 500 sec. ft. means 2.7 sec. ft. per sq. mi.; the 3 600 sec. ft., 1.28. Both of these figures will be much reduced if, as is likely, the capacity of the Amoskeag pond is increased by additional flashboards.

The Lawrence record of the Merrimack River of 1.49 sec. ft. per sq. mi, is for an average of 40 years, from 4 452 sq. mi. net and an average altitude of 1 015 ft. The Merrimack River at Garvin's Falls above Manchester has an average altitude of 1 440 ft.; Franklin Junction, 1 710 ft., and Plymouth, 2 500 ft. With results already obtained from rain gages at the high altitude stations and the greater snowfall among the high valleys, it is to be expected that the flow at Manchester will over-run the flow at Lawrence.

This paper so far has been devoted almost exclusively to the hydraulic features of the Amoskeag re-development and the existing water-power system. The electrical features are quite as important.

The author has asked the General Electric Company, which company supplied all the electrical equipment, to describe the apparatus furnished by them, and particularly the transmission, because of its unusual features and the eventual complete electrification of the largest cotton mill in the world. The writer is much indebted to E. E. Palmer of that company, through whom this request was made, and H. H. Bodge who will describe the electrical equipment and its place in the general scheme.

Thanks are also due to the officials of the Amoskeag Mfg. Company, particularly the present agent, W. P. Straw, for his kindness in putting into my hands the necessary data and suggestions from his operating department.

The turbines and generators of the new hydro station have already made good in power with the head and water on the wheels; and, if the engineer has estimated correctly, the amount of water and head under the actual conditions which will obtain, the new development will be a success, and it will need only good operation to reach the results to be expected. There is great

danger from over-confidence, and engineers have been inclined to stress the favorable features and design machinery for ideal rather than actual conditions. It is better to get good results every day in the year than to have to make a test to show what the machinery will turn out.

If a plant makes good under working conditions, every one including the operator is pulling for the new plant; if it falls down in one particular, explanations and excuses never get beyond the man in charge of the station.

DESCRIPTION OF ELECTRICAL EQUIPMENT.

BY H. H. BODGE OF THE GENERAL ELECTRIC COMPANY.

It is very unfortunate for all of us that F. L. Clarke, Electrical Engineer of the Amoskeag Company, who was to give this talk, is ill as he could have presented the subject in a much more interesting and detailed way. I have been called on at very short notice to give an outline of the electrical layout and under the circumstances my talk must be of a very general nature.

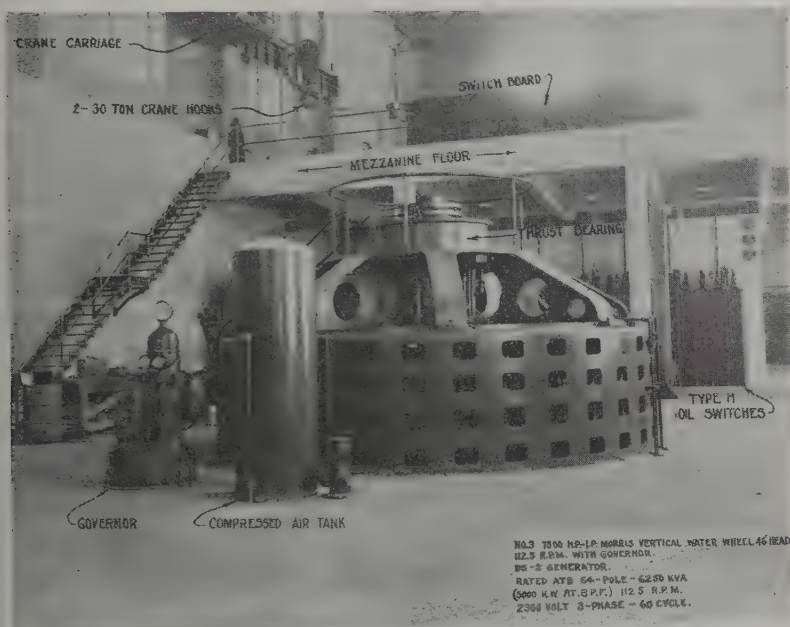
The generating units in the hydro station consist of two 6 250-kva. 2 300-volt vertical generators running at 112.5 r.p.m. with provision for one future similar unit. Two motor-driven 200-kw. exciters are installed operated at 240 volts and each equal to the ultimate excitation requirements of the station.

Provision is made in the switching equipment for six tie-line and two feeder circuits.

The switchboard, which is installed in the gallery, is of the orthodox vertical-panel type mounting all instruments, meters, protective relays, etc.

On the main generating floor across one end of the station a concrete bus and oil-circuit-breaker structure has been erected. Two rows of breakers are installed with their accompanying disconnecting switches, current transformers, etc., with busses in concrete compartments located over each row of these breakers. These busses are connected together at one end making a single U-shaped bus.

The distribution of power from the new hydro station is at present handled by eight 750 000-C.M.-triple-conductor submarine cables, six of them running from the board through the tunnel in the dam and from there into the canal system and



INSIDE OF POWER HOUSE, ONE 5 000 KW. GENERATOR AND GOVERNOR,
MEZZANINE FLOOR AND SWITCHBOARD.

down the yard to the various mills. Two of these cables are ties to the generating bus of the No. 1 Steam Station, the other four passing by this point and entering the No. 17 Substation in the Central Division. The mills on the west bank are fed over remaining two cables which run to the No. 7 Substation, so far as possible in the river bed.

One of the interesting features of the construction of the dam is that the six cables are laid in slots in the tunnel floor and provision is made for flooding these slots as an ordinary condition. The use of submarine cables in the canal system generally followed as far as possible, has been a very interesting and sat-

isfactory development. The first submarine cables were installed about fourteen years ago and then added to from time to time, and I believe there has been no trouble involving this part of the distribution. The insulation of the cables, which is largely of 750 000 C.M. size, although there are a few lengths of 500 000, is of $\frac{3}{32}$ varnished cambric around conductors, with $\frac{3}{32}$ band of the same material $\frac{1}{8}$ lead overall, with steel-wire armor. Initially the distribution in this plant was handled from a number of isolated power houses, and I believe the first installation was at 550 volts. This is still maintained but has grown so that there is about 4 000 kw. of 550-volt distribution.

The balance of the distribution is at 2 200 volts and generation is largely of this voltage.

There are some twenty generating and distributing stations, very closely interconnected. The total generating capacity is approximately 40 000 kw.

It may be noted that there are a number of large synchronous motors and although this is not clearly shown, there is about 8 000 kw. of capacity in this type of machine. As a result of this and from the fact that this capacity is pretty well distributed over the system, and for the further reason that a very large percentage of the motors used in this system are of group drive and in rather large units, the power factor of the Amoskeag system will ordinarily be found to vary between .90 and .96. The synchronous motors referred to are in most cases direct-connected to main-line shafting, driven as well by water wheels, and at times, when there is ample water, these machines may operate as generators; but I think it is safe to say that they seldom carry their full capacity as generators, and advantage is always taken of the reserve for corrective measures. It is interesting to note in this connection that in all cases Tirrell regulators are provided, and operate to hold a flat bus voltage, and they do this without, so far, having given any indication of sensitive pumping between units.

Due to the relatively large generating capacity involved and the capacity of the interconnections, a good deal of thought has been given recently to the question of the short-circuit capacity and of the ability of the general switching equipment,

some of which has been installed a great many years, to function correctly under abnormal conditions. Roughly, the short-circuit capacity at No. 1 Station and No. 17 Substation is on the order of 200 000 to 250 000 kva. This capacity is largely in excess of the ability of most of the substation equipment to handle.

A number of methods were studied to take care of this situation, and it was finally decided to put in a system of protective relays which may be of interest. Analysis was first made of each individual station. The short-circuit capacity on the bus was determined and the capacity of the individual feeder switches. As these switches were in nearly every case of the same type, a definite limit could be given to a station, above which it could be said danger existed; and such switches were provided, in addition to their inverse-time-limit relays with an instantaneous relay, with a current setting equivalent to its ultimate capacity. The contacts of this relay were connected in series with the tripping circuit of the switch, and when the current setting of the instantaneous relay was satisfied, it opened the tripping circuit of the switch and threw the duty on to a main switch large enough to handle the ultimate capacity and provided for the purpose of handling the total load of the substation.

In other words, if a feeder switch was called upon to function above its capacity, it was locked in and the whole substation was shut down. However, the locking relay is provided with a semaphore which drops and indicates immediately the circuit in trouble, and in operation this switch is immediately tripped by hand and the main switch closed.

This system is carried out in most of the substations and so far there have been five or six cases of operation of the protective switch, but as the resulting shut-down has only been a matter of a minute or so there has been no complaint on the part of the management.

Another interesting feature in connection with this involves No. 1 and No. 15 Stations which are the main-system generating stations of the plant. In the old days, and possibly to some extent today, power was exchanged with the system of the

Manchester Traction, Light & Power Company, and when this agreement was put into effect it was thought that it would be impossible for the two systems to operate together in parallel, and for this reason double busses were installed in these two generating stations, one bus called Manchester Traction Bus and the other the Amoskeag Bus. The necessity for this form of operation has now disappeared and the plants operate perfectly in parallel, but advantage was taken of the double bus in these two cases to work in a slight modification of the type of system explained above which applies mostly to the substations. It was decided to call one of the busses a generating bus and the other a distribution bus. At No. 15 Substation, which is of comparatively small capacity, a single switch was placed between the two busses and through it all the power generated passes and it becomes the main switch, protecting the feeder switches in connection with the relay lockout scheme above described. At No. 1 Station, owing to its relatively heavy capacity it was necessary to put in two 3 000 ampere switches as no single switch was developed which would carry this amount of energy and at the same time have the necessary interrupting capacity to satisfy the requirement. The physical layout of the station permitted the mills to install these switches at each end of the bus, and after some calculation and redistribution of the feeders and incoming lines, it was thought that we would be reasonably sure that a fairly even distribution of current between the two switches would be found in practice. The recommendation and the installation, however, were not made without some anxiety on this point, and it was feared that the contact resistance between the two switches would possibly vary and become so great a percentage of the total resistance in the circuit that the distribution between the two switches would be such as to cause one to be largely overloaded. Practically, however, after an operation extending something over a year, the balance has been so close that it cannot be detected on the switchboard instruments.

The entire electrical layout of the Amoskeag Company is one of the most extensive and most interesting that can be found in a manufacturing plant, and is well worthy the inspection and study by any one interested in this branch of engineering.

BOSTON SOCIETY OF CIVIL ENGINEERS

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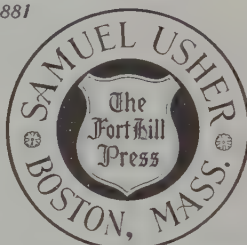
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